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Computational Models of Group Dynamics for National and International Security Applications

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Overview

Classes of problems

Algorithmic representation of social dynamics

Identify and evaluate “soft metrics”

Directions:

Mathematical models of strategic interactions

Models for soft metrics

Formalism for scenario specification

Validation and technological challenges

Knowledge bases and model refinement

Concluding remarks





Introduction: classes of problems

Aim: a methodology to build a computational framework to capture individual and group behavior.

Dimensions and attributes:

CBRNE threats: veracity

Context: geopolitical, economic

Adversary: organization

Organization: social, cultural, religious, economic



Strategic interactions/group dynamics

- Classical models:
 - Agent-based models
 - Game theory
- Social sciences, anthropology: models and computational approaches
- Policy
- Political analyses
- Goal: develop a suite of formally specified and implementable computational models of strategic interactions
- Emphasis on the formal certifiability and scalability

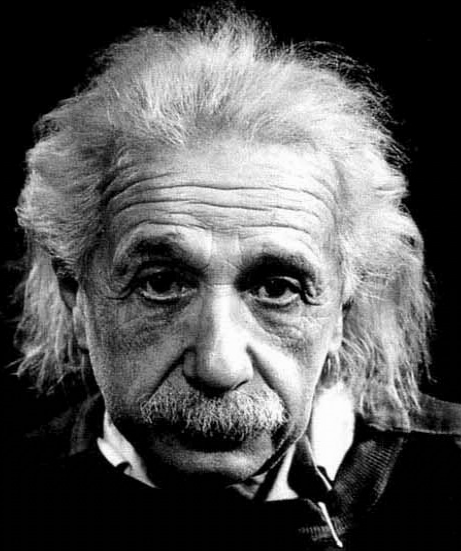


Mathematicians must justify their existence

“So far as the law of mathematics refer to reality they are not certain; and so far as they are certain, they don’t refer to reality.” Albert Einstein, 1951

“Everything should be made
as simple as possible,
but not simpler.”

Albert Einstein





Mathematical models of strategic interactions

- Priorities: the emergence of social hierarchies, the dynamics of opinions, and the emergence of leadership in social structures.
- The models will be developed in a quantitative theory of social dynamics.
- Theoretical analysis relies on techniques such as scaling, asymptotic analysis, boundary layer analysis, and extreme value statistics.
- Improved frequent patterns algorithm used to detect abnormal behaviors
- Large complex networks (CN) which have computationally intractable properties of interest



Mathematical models of strategic interactions

- Graph representation of the topology of agents' states and an update schedule capturing causal dependencies among agents.
- Measures and techniques for dynamic graph algorithms
- AGENT-BASED MODELS
- GAME THEORY
- STATISTICS
- POSSIBILITY/EVIDENCE/BELIEF/PLAUSIBILITY



Mathematical models of soft metrics

- Motivation and intent
- In a game-theoretical context: reflection of disparities among utilities
- Economic studies of long term effects
- Setting: multi-valued logic, possibility and probability measures



Implementation and validation

- Social sciences, anthropology,
- Situation theory, the theory of moves,
- In-group/out-group theory, decision theory, game theory, etc.
- Example: honor-based societies.
- Implement a prototype of formal specifications for scenarios and courses of actions
- “Universal scenario generator” that captures the most salient features of a multi-agent simulation.



Implementation and validation

- Focus on efficient representation and management of contexts
- Build a knowledge base and enhance existing models of group behavior, terrorism, infrastructures,
- Design predictive methodologies – yes, it is possible!



Validation and technological challenges

- Validation permeates the work
- Soft metrics devised for both defenders and adversaries.
- Select a *relevant* set of soft metrics
- Classes of decision agents: SME, decision makers, people.
- Technological challenges: heterogeneous database management systems, so as to resolve both syntactic and semantic conflicts.
- Research performance and functionality improvements to ensure scalability of large agent-based simulations of CN

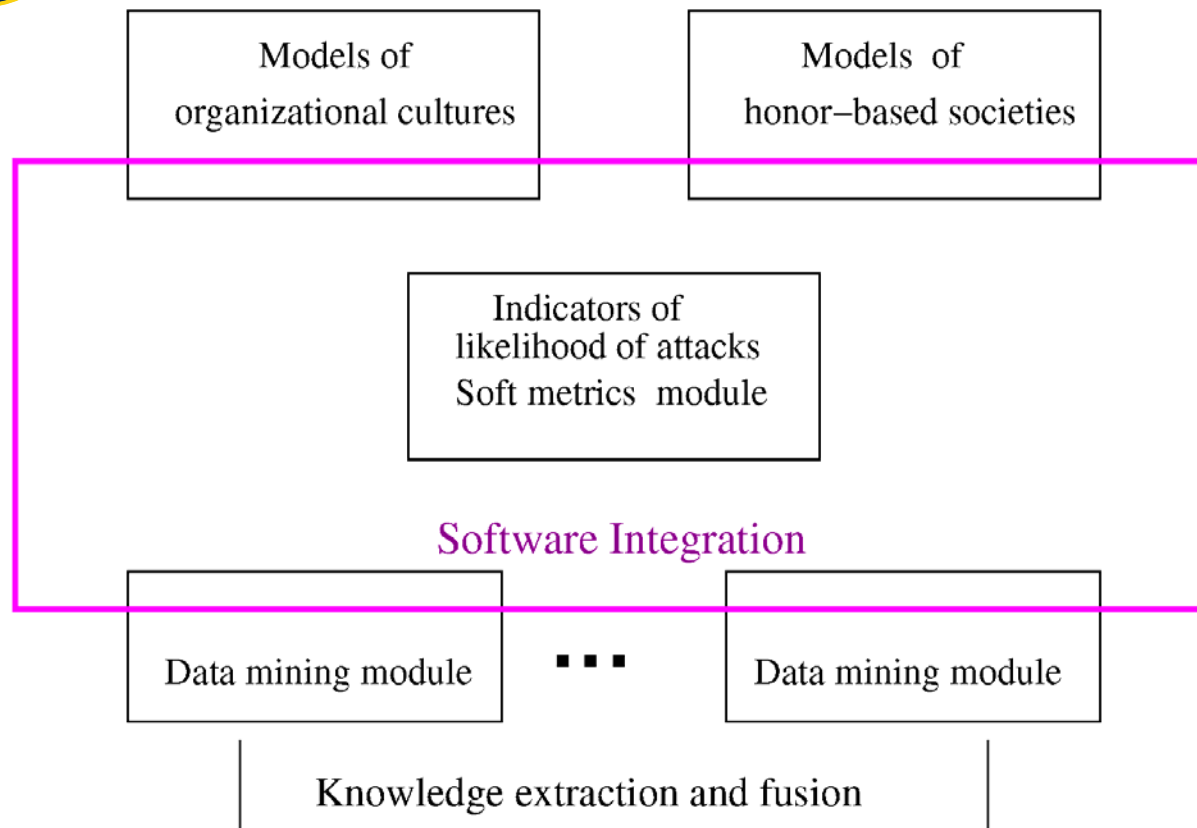


Formalism for scenario specification

- A test for the success of the method: the extent to which it can represent theoretical frameworks such as: game theory, theory of moves to model international relations, models of bounded rationality (for computational efficiency), and models of collective action.
- A formalism for specification and representation of scenarios of use for multi-agent simulations with natural language semantics (situation theory) and
- Formal verification



High level overview





Agent-based models

Simon's Bounded Rationality:

Agent-based models, following Simon (1982), also assume Bounded Rationality. "Indeed, in the absence of Turing machine (universal calculator), it is difficult not to."

Epstein (2006) reflects:

"One wonders how the core concerns and history of economics would have developed if, instead of being inspired by continuum physics ... blissfully unconcerned as it is with effective computability — it had been founded on Turing. Finitistic issues of computability, learnability, attainment of equilibrium (rather than mere existence), problem complexity, and undecidability, would then have been central from the start. Their foundational importance is only now being recognized."



Agent-based models

Epstein notes on the virtues of boundedly rational agents ...

“As Duncan Foley summarizes:

- ‘The theory of computability and computational complexity suggest that there are two inherent limitations to the rational choice paradigm.
- One limitation stems from the possibility that the agent’s problem is in fact undecidable, so that no computational procedure exists which for all inputs will give her the needed answer in finite time.
- A second limitation is posed by computational complexity in that even if her problem is decidable, the computational cost of solving it may in many situations be so large as to overwhelm any possible gains from the optimal choice of action’ (Albin 1998)”

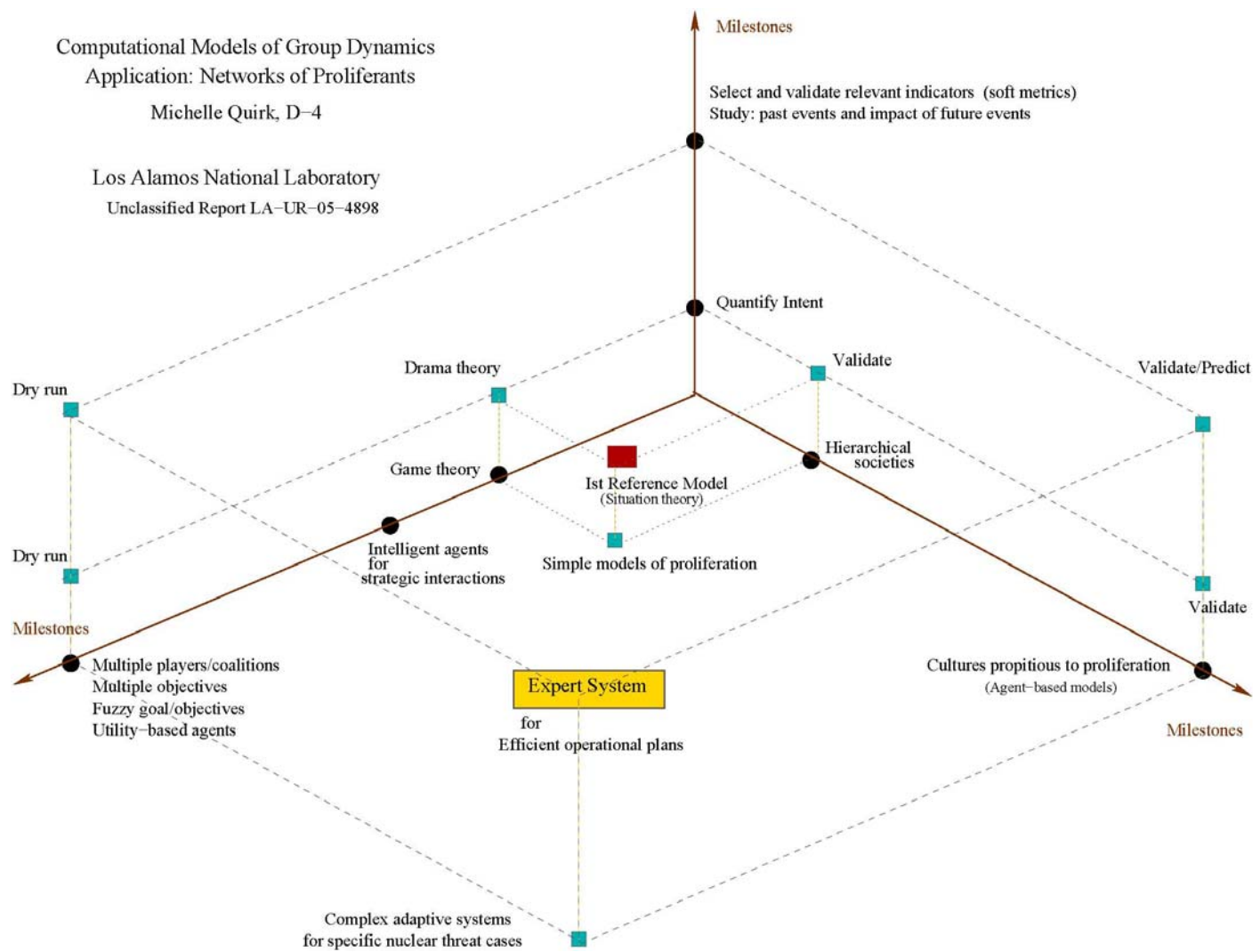


Game theory, Bayesian statistics

- Game theory: an analysis tool, not always a prediction tool
- Probabilities: too restrictive, hence misused
- Learning-based models: promising yet there is no training data



An integrated framework





Concluding remarks

- The problem dictates the method!
- Failures are unthinkable.